F°103 360 RR (3)

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04B 1/16, H04L 25/06, 27/14, 27/50

A1

(11) International Publication Number: WO 00/16490

(43) International Publication Date: 23 March 2000 (23.03.00)

(21) International Application Number: PCT/SE99/01535

(22) International Filing Date: 3 September 1999 (03.09.99)

(30) Priority Data: 9803133-9 15 September 1998 (15.09.98) SE

(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE).

(72) Inventor: KORSFELDT, Dan; Älvdalsvägen 55, S-165 75 Hässelby (SE).

(74) Agent: ERICSSON RADIO SYSTEMS AB; Common Patent Dept., S-164 80 Stockholm (SE).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, ~~UG~~, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

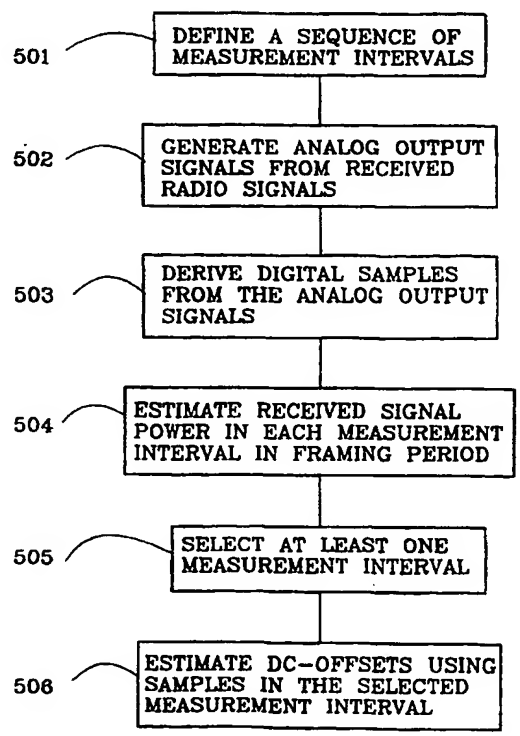
Published

With international search report.
With amended claims.

(54) Title: METHOD AND ARRANGEMENT IN A RADIO RECEIVER

(57) Abstract

The invention relates to a method and an arrangement for estimating a DC-offset in at least one analog output signal from an analog front end of a radio receiver in a TDMA-based radio communication system. A sequence of measurement intervals is defined (501) such that for each burst transmitted on a radio carrier frequency by mobile stations operating in a common cell, there is at least one measurement interval during which no overlap with a second burst occurs. The analog front end of the radio receiver generates (502) the analog output signal by performing analog signal processing of received radio signals. Digital samples are derived (503) from the analog output signal. A measure of received signal power in each measurement interval in a framing period is estimated (504). At least one measurement interval during the framing period is selected (505) in dependence of said measure. The DC-offset is estimated (506) using samples belonging to said selected measurement interval.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

METHOD AND ARRANGEMENT IN A RADIO RECEIVER

TECHNICAL FIELD OF THE INVENTION

The invention relates to a method and an arrangement in a radio receiver for use in a TDMA-based radio communication system. More specifically the invention relates to a method and arrangement for estimating a DC-offset generated in an analog front end of the radio receiver.

DESCRIPTION OF RELATED ART

Radio receivers, with the possible exception of radio receivers used in pure analog radio communication systems, comprises an analog front end and a digital back end. The analog front end of a radio receiver receives radio signals from an antenna and performs analog signal processing, such as amplification, filtering and frequency down conversion, of the received radio signal resulting in at least one analog output signal from the analog front end to the digital back end. In e.g. second generation cellular systems such as Digital Advanced Mobile Phone System (D-AMPS), Personal Digital System (PDC) and Global System for Mobile communications (GSM) and evolutions of said systems such as Enhanced Data rates for GSM (EDGE), the analog front end typically provides the digital back end with two output signals, one inphase signal (I-signal) and one quadrature signal (Q-signal).

A well known problem arising in the radio receiver is that each output signal from the analog front end comprises an unwanted DC-offset component which is generated by the analog front end due to e.g. local oscillator leakage and component mismatches. A radio receiver needs to include some kind of DC-offset correcting means, since the DC-offset otherwise would cause a serious degradation of the radio receiver performance.

U.S. Patent 5,422,889 teaches a direct conversion receiver, i.e. a homodyne receiver, including an offset correction circuit, for use in a TDMA-based radio communication system. The offset

correction circuit determines and uses two different kinds of offset correction values when compensating for a DC-offset introduced in an analog front end of the receiver. In the radio communication system an assigned time slot on a radio carrier comprises a leading part containing no information to be detected and a data part containing transmitted information.

A single offset correction value is determined during the leading part of the assigned timeslot by inhibiting the received modulated carrier to reach the mixer and adjusting the single offset correction value until it balances the DC-level from the analog front end.

A set of variable parameter offset correction values is determined corresponding to each possible combination of radio carrier frequency and gain mode. Upon occurence of an assigned time slot, an updated offset correction value for the relevant carrier frequency/gain mode combination is determined as a function of an old offset correction value for said combination and an average value of the sampled output signal from the analog front end during the data part of the assigned time slot.

The single offset correction value is applied for compensation of the DC-offset until the variable parameter offset correction values, which can provide more accurate correction, have been sufficiently updated.

The British patent GB 2,267,629 describes a method and apparatus for reducing signal errors in GSM radio receivers. A received signal burst is demodulated to produce inphase and quadrature baseband signals which are digitised to provide a set of signal-value pairs, each consisting of an I-value and a corresponding Q-value in one bit period of the burst.

DC-offsets in the I and Q signal paths are cancelled by determining the average I-value and average Q-value over the burst and substracting these average values respectively from the I- and Q-values of each signal value pair. The DC-cancellation operation is followed by a DC-restoration operation

to compensate for a possible DC-content in the received signal burst.

SUMMARY OF THE INVENTION

The present invention addresses the problem of estimating a DC-offset in at least one analog output signal from an analog front end of a radio receiver in a time division multiple access (TDMA) based radio communication system.

The problem is solved essentially by a method and arrangement in which a sequence of measurement intervals is defined such that, regardless of how the sequence of measurement intervals is shifted in time relative to a structure of bursts transmitted on a radio carrier frequency by mobile stations operating in a common cell, there is for each transmitted burst, at least one measurement interval during which no overlap with a second burst occurs. The DC-offset is estimated based on output signals from the analog front end during selected ones of said measurement intervals.

More specifically, the problem is solved in the following manner. The sequence of measurement intervals is defined such that the distance between measurement intervals together with the length of measurement intervals fulfil certain criteria ensuring that, regardless of how the sequence of measurement intervals is shifted in time relative to said transmitted burst, there is at least one measurement interval for each transmitted burst during which no overlap with a second burst occurs. The analog front end of the radio receiver generates the at least one analog output signal by performing analog signal processing of received radio signals including the bursts transmitted by the mobile stations on the radio carrier. Digital samples are derived from the at least one analog output signal. A measure of received signal power in each measurement interval in a framing period is estimated. At least one measurement interval during the framing period is selected in dependence of said estimated

received signal power. The DC-offset is estimated using samples among the digital samples which belong to said selected measurement interval.

According to one embodiment of the invention the DC-offset is estimated as an average of at least a subset of samples belonging to said selected measurement interval.

According to another embodiment of the invention the DC-offset is estimated as an running average of at least a subset of samples belonging to the selected measurement interval in at least two consecutive framing periods.

A general object of the invention is to provide a method and arrangement for estimating a DC-offset in at least one output signal from an analog front end of a radio receiver operating in a TDMA-based radio communication system and receiving radio signals transmitted by mobile stations on a radio carrier frequency.

A more specific object is to provide such a method and arrangement for estimating the DC-offset that do not require the radio receiver and the mobile stations to be synchronized.

Yet another object is to provide a method and arrangement for estimating the DC-offset that provides DC-offset estimates fast fast enough to enable the radio receiver to adjust to variations in the DC-offset e.g. due to temperature variations.

One advantage afforded by the invention is that the radio receiver and the mobile stations transmitting the radio signals received by the radio receiver need not be synchronized.

Another advantage of the invention is that DC-offsets can be provided fast enough to enable the radio receiver to adjust to variations in the DC-offset e.g. due to temperature variations.

The invention will now be described in more detail with reference to exemplifying embodiments thereof and also with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view illustrating part of a TDMA based radio communication system.

Fig. 2 is a time-frequency diagram illustrating three digital traffic channels.

Fig. 3 is a block schematic illustrating a low-IF superheterodyne receiver according to a first embodiment of the present invention.

Fig. 4 is a time diagram illustrating a sequence of measurement periods.

Fig. 5 is a flowchart of the general method for estimating a DC-offset according to the present invention.

Fig. 6 is a block schematic illustrating function blocks in a DC-estimator.

Fig. 7A is a time diagram illustrating the relative positions of measurement intervals in a first measurement sequence with respect to TDMA-frames on a radio carrier frequency.

Fig. 7B is a time diagram illustrating the relative positions of measurement intervals in a second measurement sequence with respect to TDMA-frames on a radio carrier frequency.

Fig. 8 is a block schematic illustrating a homodyne receiver according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig. 1 shows part of a TDMA radio communication system PLMN1, which in this example is a mobile telephony network using a

radio interface according to the TIA/EIA IS-136 specification. The radio communication system PLMN1 comprises a first base station BS1 and a second base station BS2 connected to a mobile services switching centre MSC1. The communication system PLMN1 also comprises a first, a second and a third mobile station MS1-MS3. In this example scenario all three mobile stations MS1-MS3 are operating within an area, i.e. cell, served by the first base station BS1.

All the mobile station MS1, MS2 and MS3 are in active communication with the first base station BS1 and have each been assigned one digital traffic channel DTC1, DTC2 and DTC3 respectively. The mobile stations MS1-MS3 transmit information to the first base station BS1 in the forward, i.e. uplink, portion of the respective traffic channel DTC1-DTC3 and receives information from the first base station BS1 in the reverse, i.e. downlink, portion of the respective digital traffic channel DTC1-DTC3.

Fig. 2 illustrates the digital traffic channels DTC1-DTC3 of this example scenario in the time TI and frequency FREQ domains. Note that with respect to the time domain, Fig. 2 illustrates the situation as viewed at the first base station BS1.
In the frequency domain FREQ, the forward portions of the digital traffic channels DTC1-DTC3 all use a common first radio carrier frequency RCF1. According to the TIA/EIA IS-136 specification, this implies that the backward portions of the digital traffic channels DTC1-DTC3 all use a common second radio carrier frequency RCF2.
In the time domain TI both radio carrier frequencies RCF1-RCF2 are divided into equally sized time slots TS1-TS6. A group of six consecutive time slots forms a TDMA-frame TDMA1. The TDMA-frame length is 40 ms and thus the time slot length is 6.67 ms. The time slot length expressed in terms of radio symbols is exactly 162 radio symbols. In this example scenario all the digital traffic channels DTC1-DTC3 are full-rate channels i.e.

each channel is assigned two equally spaced time slots of the frame. Thus DTC1 is assigned timeslots TS1 and TS4, DTC2 utilizes timeslots TS2 and TS5 and DTC3 utilizes timeslots TS3 and TS6. As illustrated in Fig. 2, the time slot structures of the second radio carrier frequency RCF2 is shifted relative to the time slot structure of the first radio carrier frequency RCF1. Communication between the first base station BS1 and the mobile stations MS1-MS3 on the digital traffic channels DTC1-DTC3 occurs by transmission of radio signals in the form of bursts of radio symbols in time slots assigned to the respective digital traffic channel DTC1-DTC3 on either the first radio carrier frequency RCF1 or the second radio carrier frequency RCF2. The mobile stations MS1-MS3 are synchronized to the stream of bursts they receive from the first base station BS1 in the downlink portion of the respective assigned digital traffic channel DTC1-DTC3. Based on when the mobile stations MS1-MS3 receives said bursts from the first base station BS1, the mobile stations MS1-MS3 determine when they should transmit bursts in the reverse portion of the respective digital traffic channel DTC1-DTC3.

As illustrated in Fig. 1, depending on the geographical position of each mobile station MS1-MS3 the distance between the first base station BS1 and the respective mobile station MS1-MS3 varies. This implies that the transmission delay, with respect to bursts transmitted by the different mobile stations MS1-MS3 and received by the first base station BS1, also varies. Since it is important that at the first base station BS1 bursts transmitted by the different mobile stations MS1-MS3 do not overlap each other, i.e. that the bursts transmitted in the reverse portion of the respective digital traffic channel DTC1-DTC3 are received by the first base station BS1 in the time slots assigned to the respective digital traffic channel DTC1-DTC3, the TIA/EIA IS-136 specification defines a time alignment procedure for adjusting the transmission time of the mobile stations MS1-MS3 so that the transmitted bursts arrive in the

proper time slots at the first base station BS1. The first base station BS1 determines a proper timing advance value for each mobile station MS1-MS3 and informs each mobile station MS1-MS3 of how much it should advance its transmissions with respect to a standard offset reference. A mobile station near the first base station BS1 is provided with a zero timing advance value while a mobile station further away from the first base station BS1 may be ordered to advance its burst transmissions up to a maximum timing advance value of 15 radio symbols. In the example scenario illustrated in Fig. 1 the second mobile station MS2 and the third mobile station MS3 are assumed to be using the maximum timing advance value of 15 radio symbols, while the first mobile station MS1, being closer to the first base station BS1 than the other two base stations MS2-MS3, uses a timing advance value less than 15 radio symbols. Note that even though the time alignment procedure sees to it that the first base station BS1 may receive bursts transmitted by the mobile stations MS1-MS3 without any overlap despite the varying distances between the first base station BS1 and each respective mobile station MS1-MS3, if an attempt is made to receive these bursts at the second base station BS2, they will partly overlap each other.

In the example scenario illustrated in Fig. 1, the second mobile station MS2 is moving away from the first base station BS1 and towards the second base station BS2. TIA/EIA IS-136 specifies a mobile assisted handoff function and for this purpose, the second mobile station MS2 performs measurements on its assigned digital traffic channel DTC2 and on radio signals from neighbour base stations, including the second base station BS2. The results of these measurements are reported to the first base station BS1. As the second mobile station MS2 approaches the second base station BS2 the signal strength on the digital traffic channel DTC2 decreases while the signal strength of the signals from the second base station BS2 increases. The first base station BS1 evaluates the results reported from the second mobile station MS2 as well as results of its own measurements on

the digital traffic channel DTC2. When a handoff trigger criterion is fulfilled, the first base station BS1 sends a handoff request message to the mobile services switching centre MSC1, identifying the second base station BS2 as the primary target for a hand off. The mobile services switching centre MSC1 sends a verification request message to the second base station BS2 ordering the second base station BS2 to verify that the second base station BS2 can receive the transmissions from the second mobile station MS2 in the reverse portion of the digital traffic channel DTC2. The second base station BS2 tunes a radio receiver 101 to the second radio carrier frequency RFC2 and tries to measure and evaluate the decoded digital verification color code, the received signal strength and the received burst quality.

In order for the second basestation BS2 to perform the verification task, the radio receiver 101 needs to be able to detect and decode radio symbols in the bursts transmitted on the the second radio carrier frequency RFC2. The radio receiver 101 comprises an analog front end 102 connected to a digital back end 103. The analog front end 102 performs analog signal processing of received radio signals producing two analog output signals, one inphase signal (I-signal) and one quadrature signal (Q-signal). The two analog output signals are received by the digital back end 103. The digital back end 103 converts the analog output signals into digital signals which are then digitally processed.

A problem in the radio receiver 101 is that the analog front end circuitry generates DC-offsets in the analog output signals. These DC-offsets have a number of contributing sources such as local oscillator leakage and component mismatches. A DC-offset for an analog output signal with a dynamic range of 0 - 2.5 V, may typically be of the order +/- 10 mV, have a temperature variation of 0.1 mV per degree and change up to 6 mV when changing between different radio carrier frequencies. In order to prevent the DC-offsets from seriously degrading the radio

receivers 101 capability of correct detection of received radio symbols, the radio receiver 101 must include means for estimating the DC-offsets such that the radio receiver 101 may compensate for these DC-offsets.

The DC-offsets may be estimated in the digital back end 103 of the radio receiver 101 from the digital signals corresponding to the analog output signals from the analog front end 102. This estimation may be based on an expectation that the average DC-content of the received radio signals is zero. However, individual radio symbols transmitted by the mobile stations MS1-MS3 and received by the radio receiver 101 do have DC-content which is proportional to the amplitude of the received radio symbols. Thus sufficiently many samples in said digital signals belonging to sufficiently many radio symbols must be used when estimating the DC-offsets in order to provide good DC-estimates. A problem complicating the situation is that the difference in received signal strength of bursts transmitted by the different mobile stations MS1-MS3 may be up to 60-70 dB. Detection of radio symbols in a weak burst requires better DC-offset estimates than detection of radio symbols in a strong burst. Furthermore, if DC-offset estimates of a certain precision is arrived at after using samples of weak bursts, in order to provide DC-offset estimates of the same precision when using samples of much stronger bursts, a longer sequence of samples is needed. Thus, if DC-estimates based on radio symbols in strong bursts were to be used for DC-offset correction when detecting radio symbols in a weak burst, a very long sequence of samples would have to be used in order to yield good enough DC-estimates. For example, if bursts transmitted by mobile stations MS1 and MS2 were to have a received signal strength 60 dB higher than bursts transmitted by the mobile station MS3, a sample sequence of magnitude 14 minutes would have to be used. Such long sample sequence are far to long to enable the DC-offset estimates to track changes in the DC-offsets caused by e.g. temperature variations in the radio receiver 101.

The end result is that in order to be able to use DC-offset estimates based on relative short sample sequences when detecting radio symbols received from a mobile station, these DC-offset estimates need to be based on samples either of bursts transmitted by the same mobile station, on samples of bursts received with less signal strength or on samples of empty time slots, i.e. time periods during which no bursts are transmitted. A further complication with regards to DC-offset estimation in the context of the present example scenario is that the radio receiver 101 and the mobile stations MS1-MS3 are not synchronized and thus the radio receiver 101 do not know when bursts transmitted by the respective mobile stations MS1-MS3 begins and ends. Furthermore, as explained previously, bursts transmitted by the different mobile stations MS1-MS3 and received by the radio receiver 101 in the second base station BS2 partly overlap each other.

Fig. 5 illustrates the general method according to the present invention for estimating the DC-offsets in the two analog output signals from the analog front end 102 of the radio receiver 101 in Fig. 1.

At step 501 a sequence of measurement intervals is defined. This sequence of measurement intervals is defined as illustrated in Fig. 4.

Fig. 4 is a time diagram illustrating a pattern of first regions 401 and second regions 402 in the time domain TI. The first regions 401 have each a pretermined length L1. The centres of two consecutive first regions are separated by a distance D1 equal to one time slot, i.e. 162 radio symbols according to TIA/EIA IS-136. Each of the second regions 402 extends between consecutive first regions 401. Each of the first regions 401 is intended to have a length L1 such that, assuming the pattern would be properly aligned to the timing of the bursts transmitted by the mobile stations MS1-MS3 on the second radio carrier frequency RFC2, there is a neglible risk that two bursts

received by the second base station BS2 will overlap each other outside the first regions 401. In the scenario illustrated in Fig. 1, where both the second mobile station MS2 and the third mobile station MS3 are using the maximum timing advance value according to the EIA/TIA IS-136 specification, the required length L1 of the first regions 401 is twice the maximum timing advance value, i.e. 30 radio symbols. The maximum timing advance value according to the EIA/TIA IS-136 specification is only used for communication in large macro cells. Thus assuming that the cell served by the first base station BS1 is a smaller cell, e.g. a micro cell, an effective maximum timing advance value used by the mobile stations MS1-MS3 when transmitting bursts on the second radio carrier frequency RCF2 would be less than the maximum timing advance value of 15 radio symbols defined in the TIA/EIA IS-136 specification. When such an effective maximum timing advance value is used, it suffices that the first region length L1 is twice the effective maximum timing advance value.

The sequence of measurement intervals 410 is defined such that for any first measurement interval 411 in the sequence, there is a subsequent measurement interval 412 which together with the first measurement interval 411 fulfil the following two criteria:

- the distance D2 between the first measurement interval 411 and the second measurement interval is greater than the length L1 of a first region 401;
- the distance D3 from the beginning of the first measurement interval 411 to the end of the second measurement interval 412 is less than the length L2 of a second region 402.

At step 502 in Fig. 5, the analog front end 102 generates the analog output signals by performing analog signal processing, such as amplification, filtering and frequency down conversion, of radio signals received by the radio receiver 101. These radio signals include the radio signals transmitted by the mobile stations MS1-MS3 on the second radio carrier frequency RCF2.

At step 503 digital samples are derived from the two analog output signals from the analog front end 102. This step includes at least analog-to-digital conversion of the two analog output signals, but may also comprise further digital signal processing such as frequency conversion and filtering in the digital backend 103. Since the general trend is to minimize the amount of signal processing in the analog front end 102, step 503 will typically comprise further digital signal processing in the digital backend 103.

At step 504, the digital samples are used to estimate a measure of received signal power for each measurement interval in a framing period. The framing period length is selected such that transmissions from all the mobil stations MS1-MS3 currently assigned a digital traffic channel DTC1-DTC3 on the second radio frequency carrier RFC2 may be received within a framing period. Thus the framing period may be selected as a framing period of length corresponding to one TDMA-frame. However, the mobile telephony network PLMN1 illustrated in Fig. 1 is assumed to support only fullrate digital traffic channels. Since this implies that the assignment of time slots on a radio carrier frequency to digital traffic channels are repeated after three time slots, i.e. a half TDMA-frame, an alternative and preferred way of selecting the framing period in the context of the present example scenario is as a framing period FP2 of length corresponding to half a TDMA-frame. The framing period FP2 is illustrated in Fig. 4.

At step 505 at least one measurement interval in the framing period is selected in dependence of the previously estimated measures of received signal power. A preferred way of selecting is to select the measurement interval having the weakest received signal strength.

At step 506 the DC-offset is estimated using samples among said digital samples which belong to said selected measurement interval.

One way of estimating the DC-offset is to determine an average of at least a subset of the samples belonging to the selected measurement interval.

Another way of estimating the DC offset is to determine a running average of at least a subset of the samples belonging to the selected measurement interval in at least two consecutive framing periods.

Fig. 3 illustrates a radio receiver 301 according to a first examplifying embodiment of the invention. The radio receiver 301 is well suited for use e.g. as the radio receiver 101 in the second base station BS2 in Fig. 1.

The radio receiver comprises an analog front end 302 and a digital back end 303.

The analog front end 302 performs analog signal processing of a radio signal S31 from an antenna 304 as follows. A high frequency block 305 amplifies and filters the radio signal S31. The output signal from the high frequency block 305 is down converted to a first intermediate frequency by a first mixer 306. The first mixer 306 is fed by an oscillating sine signal, having a frequency f_{LO1}, from a first local oscillator 307. The frequency f_{LO1} is selected in dependence of which radio carrier frequency the radio receiver 301 is tuned to, such that the down converted signal is centered around a first intermediate frequency f_{IF1} of 100 MHz. The output signal from the first mixer 306 is fed to an intermediate frequency block 308. The intermediate frequency block 308 filters and amplifies the output signal from the first mixer 306. The output signal from the intermediate frequency block 308 is fed in parallell to a second and a third mixer 310-311 respectively. The second mixer 310 and the third mixer 311 are fed by a pair of oscillating sine signals in quadrature. The second mixer 310 is fed directly from a second local oscillator 312 generating an oscillating signal having a frequency f_{LO2} of 99.985 MHz. The third mixer 311 is fed from the second local oscillator 312 via a phase shifter

causing a delay corresponding to a phase shift of $\pi/2$. Output signal S32 from the second mixer 310 together with output signal S33 from the third mixer 311 constitutes analog output signals from the analog front end 302. The output signals S32-S33 from the analog front end 302 are not baseband signals, but contain a carrier rest of 15 kHz. For this reason and due to the receiver structure, the radio receiver 301 may be labeled as a low-IF superheterodyne receiver.

In the digital back end 303 of the radio receiver 301, the two output signals S32-S33 from the analog front end 302 are converted into a pair of digital signals S34-S35 by a pair of analog-to-digital converters 314-315. The analog-to-digital converters are operating at a sampling frequency f_s of 194.4 kHz. The digital signals S34-S35 are down converted to the base band, i.e. the remaining carrier rest of 15 kHz are removed from the respective signal S34-S35, in a first complex digital mixer 316. The respective output signal from the first complex digital mixers 316, are filtered in a pair of baseband finite response filters (FIR) 318-319. The respective output signal from the pair of finite response filters 318-319 are then upconverted in a second complex digital mixer 320 so that the output signals S36-S37 from the second complex digital mixer 320 once more contains a carrier rest of 15 kHz. The respective output signal S36-S37 from the second complex digital mixer are fed in to a DC-offset estimator 322. Based on the output signals S36-S37 from the second complex digital mixer 320, the DC-offset estimator 322 provides a first DC-offset estimate DC31 for correction of signal S36 and a second DC-offset DC32 for correction of signal S37. The respective DC-offset estimates DC31-DC32 are substracted from the respective output signal S36-S37 from the second complex digital mixer 320 in a pair of adders 324-325, i.e. the respective DC-offset estimate DC31-DC32 are subtracted from each sample in the respective output signal S36-S37. Note that the DC-offset estimator 322 continuously updates the DC-offset estimates DC31-DC32 in accordance with

samples in the signals S36-S37 in order to track changes in the DC-offsets generated by the analog front end 302. In a third complex digital mixer 326 the respective output signal from the pair of adders 324-325 are downconverted to the base band. Finally, a detector unit 328 receives the output signals from the third complex digital mixer 326 and uses these signals to perform radio symbol detection.
The analog-to-digital converters 314-315, the first complex digital mixer 316, the FIR-filters 318-319 and the second complex digital mixer 320 may collectively be reagrded as a means for deriving the digital signals S36-S37, i.e. digital samples, from the two analog output signals S32-S33 generated by the analog front end 302.

Fig. 6 provides further details on the internal structure of the DC-offset estimator 322. The DC-offset estimator 322 comprises a sample arranger 601 which receives the pair of digital signals S36-S37 from the second complex digital mixer 320 in Fig. 3. The pair of digital signal S36-S37 can be described as a complex digital signal

$$S_{in}(k) = I_{in}(k) + j^*Q_{in}(k) \qquad (1)$$

where k is an index variable, I(k) represents samples in the digital signal S36 and Q(k) represents samples in the digital signal S37. If $S_{in}(k_0)$, i.e. $I_{in}(k_0) + j^*Q_{in}(k_0)$, is a first complex sample of a received radio symbol, then all complex samples upto $S_{in}(k_0+7)$ are samples of the same received radio symbol, i.e. each radio symbol results in 8 complex samples.

The sample arranger 601 groups samples in the complex digital signal $S_{in}(k)$ into sets of samples corresponding to measurement intervals in a sequence of measurement intervals. The measurement intervals are defined such that the criteria described in connection with Fig. 4 are fulfilled. In this particular embodiment each measurement interval is of a length corresponding to 49 radio symbols and the distance between two

consecutive measurement intervals corresponds to 32 radio symbols. Thus each group of samples corresponding to a measurement interval consists of 392 consecutive samples. The distance between to measurement intervals corresponds to 256 samples, i.e. if sample $S_{in}(k_{last})$ is the last sample in a group of samples corresponding to a measurement interval, the first sample in the group of samples corresponding to the next measurement interval is sample $S_{in}(k_{last}+257)$.

Each group of samples corresponding to a measurement interval are processed in parallell by a power estimator 602 and a measurement interval average estimator 603.

The power estimator 602 forms a power measure estimate P for the measurement interval as a sum

$$P = \sum_{n=0}^{(L\cdot 8/R)-2} \left|I_{in}(n_0+n\cdot R)-I_{in}(n_0+(n+1)\cdot R)\right| + \left|Q_{in}(n_0+n\cdot R)-Q_{in}(n_0+(n+1)\cdot R)\right| \quad (2)$$

where n is an index variable,
n_0 is the index of the first complex sample $S_{in}(n_0)$ in the group of samples corresponding to the measurement interval
L = 49 is the measurement interval length expressed as number of radio symbols and
R = 4 is a constant controlling which samples are used when forming the power measure estimate.

In expression (2), samples $S_{in}(n_0)$, $S_{in}(n_0+4)$, $S_{in}(n_0+8)$… $S_{in}(n_0+96)$ are used, i.e. the used samples forms a subset comprising the first sample and then each fourth sample of the samples in the group corresponding to the measurement interval. Using each fourth sample implies that two samples per received radio symbol is used when forming the power measure estimate P. The power measure estimate P is formed as a sum of the distances in the real and imaginary parts between consequtive samples in said subset of samples.

The measurement interval average estimator 603 forms a complex average A of said subset of samples used when estimating the received signal power during the measurement interval i.e.

$$A = (R/(L\cdot 8))\cdot\sum_{n=0}^{(L\cdot 8/R)-1} S_{in}(n_0+n\cdot R) \quad (3)$$

The power measure estimate P and the average A for each measurement interval are supplied to a selector 604 in pairs. The selector stores power measure estimates and averages for six consecutive measurement intervals, corresponding to a framing period of a half TDMA-frame, before the selector among said six consecutive measurement intervals selects the measurement interval having the least power measure estimate. The selector 604 passes the average A for the selected measurement interval to a DC-level estimator 605. The DC-level estimator 605 estimates a complex DC-offset estimate as a running average of the four latest selected measurement interval averages A_1-A_4 received from the selector 604. The complex DC-offset estimate is thus determined as .

$$V_{DC\_est} = (1/4)\cdot\sum_{n=1}^{4} A_n \quad (4)$$

The first DC-offset estimate DC31 constitutes the real part of the complex DC-offset V_{DC_est} while the second DC-offset estimate DC32 constitutes the imaginary part of the complex DC-offset V_{DC_est}. The DC-offset estimates DC31 and DC32 are stored in a storage unit 606. Since a new complex DC-offset V_{DC_est} is computed at the end of each framing period, the DC-offset estimates DC31 and DC32 are updated at the end of each framing period. This implies that the DC-offset estimates DC31-DC32 used when correcting the respective digital signals S36-S37 during a framing period was determined during the immediately preceeding framing period.

Fig. 8 illustrates a radio receiver 801 according to a second examplifying embodiment of the invention. The radio receiver 801 is of homodyne type i.e. received radio signals are directly converted down to base band frequencies.

The radio receiver 801 comprises an analog front end 802 and a digital back end 803.
The analog front end 802 performs analog signal processing of a radio signal S81 received from an antenna 804 as follows. A high frequency block 805 amplifies and filters the radio signal S81. The output signal from the high frequency block 805 is fed in parallell to a first and a second mixer 806-807 respectively. The first mixer 806 and the second mixer 807 are fed by a pair of oscillating sine signals in quadrature. The first mixer 806 is fed directly from a first local oscillator 808 generating an oscillating signal having a frequency f_{LO}. The frequency f_{LO} is equal to the radio carrier frequency the radio receiver 801 is tuned to. The second mixer 807 is fed from the local oscillator 808 via a phase shifter 809 causing a delay corresponding to a phase shift of $\pi/2$. The output signals from the first mixer 806 and the second mixer 807 are fed to a first analog base band block 810 and a second analog base band block 811 respectively. The output signals from the respective mixer 806-807 are first low pass filtered and then amplified in the respective analog base band block 810-811. Output signals S82 from the first analog base band block 810 together with output signal S83 from the second analog base band block 811 constitutes analog output signals from the analog front end 802. The output signals S82-S83 from the analog front end 802 are baseband signals.

In the digital back end 803 of the radio receiver 801, the two output signals S82-S83 from the analog front end 802 are converted into a pair of digital signals S84-S85 by a pair of analog-to-digital converters 812-813. The analog-to-digital converters are operating at a sampling frequency f_s of 194.4 kHz. The digital signals S84-S85 are filtered in a pair of

baseband finite response filters (FIR) 814-815. The respective output signal S86-S87 from the finite response filters are fed in to a DC-offset estimator 816. Based on the output signals S86-S87 from the baseband finite response filters (FIR) 814-815, the DC-offset estimator 816 provides a first DC-offset estimate DC81 for correction of signal S86 and a second DC-offset DC82 for correction of signal S87. The respective DC-offset estimates DC81-DC82 are substracted from the respective output signal S86-S87 from the finite response filters 814-815 in a pair of adders 817-818, i.e. the respective DC-offset estimate DC81-DC82 are subtracted from each sample in the respective output signal S86-S87. Finally, a detector unit 819 receives the output signals from the pair of adders 817-818 and uses these signals to perform radio symbol detection.

Fig. 6 provides a valid illustration of the internal structure of the estimator 816 in Fig. 8. When applying Fig. 6 to the estimator 816 in Fig. 8, digital signals S36-S37 are replaced by digital signals S86-S87 and DC-estimates DC31-DC32 are replaced by DC-estimates DC81-DC82. The basic operation of each of the elements in Fig. 6 is the same as previously discussed and expressions (1) - (4) are valid also in this case with some minor modifications. In expression (2) and (3) the constant R is changed to R = 8, i.e. each eight sample in the digital signals S86-S87 are used when calculating the power estimate P and the average A. It is further recommended that in expression (4) the complex DC-offset estimate V_{DC_est} is calculated as a running average of the 128 latest selected measurement intervals. These modifications are due to the fact that the analog output signals S32-S33 from the analog front end 302 contains a carrier rest of 15 kHz while the analog output signals S82-S83 from the analog front end 802 are base band signals, which causes the received radio symbols in the signals S32-S33 to have different properties as compared to the received radio symbols in the signals S82-S83. Primarily it is the difference in DC-content of individual radio symbols that is of importance for the present

invention. Individual radio symbols in the signals S32-S33 comprising a 15 kHz carrier rest have a significantly lower DC-content than individual radio symbols in the baseband signals S82-S83. Thus, for the radio receiver 801 in Fig. 8 a greater number of selected measurement intervals is needed when calculating the complex DC-offset estimate V_{DC_est} as compared to the number of measurement intervals used when performing the corresponding calculation for the radio receiver 301 in Fig. 3.

Yet a third examplifying embodiment of the invention is arrived at by replacing the analog front end 302 of the radio receiver 301 in Fig. 3 with the analog front end 802 in Fig. 8 and modifying the first local oscillator 808 to generate an oscillating sine signal having a frequency such that the output signals from the analog front end 802 contain a carrier rest of 15 kHz. Such a replacement of the analog front end do not require any modifications to the digital backend 303 in Fig. 3.

In addition to the examplifying embodiment of the invention described above, there are several other possible embodiments of the current invention, some of which are discussed down below.

Both the radio receiver 301 in Fig. 3 and the radio receiver 801 in Fig. 8 use a measurement interval sequences wherein each measurement interval is of length corresponding to 49 radio symbols and the distance between two consecutive measurement intervals is of length corresponding to 32 radio symbols. This implies that the relative position of the measurement intervals in the measurement sequence remains static with respect to the TDMA-frames on the second radio carrier frequency RCF2 in Fig 2. Fig. 7A is a time diagram illustrating said static relationship between the measurement intervals and TDMA-frames. In Fig. 7A a measurement interval 701 begins at a first point in time T701 along the time axis TI. Another measurement period 702 begins at a second point in time T702 one TDMA-frame period 703 after the first point in time T701.

A possible and desirable modification of the above described measurement interval sequence is to define the sequence such that the relative positions of the measurement intervals with respect to each consecutive TDMA-frame slowly changes, e.g. half a radio symbol up to 1-2 radio symbol per TDMA-frame period. This modified measurement interval sequence is illustrated in the time diagram of Fig. 7B. In Fig. 7B a measurement interval 704 begins at a first point in time T704 along the time axis TI. At a second point in time T705 one TDMA-frame period 703 after the first point in time T704, there is a short offset 706 to the beginning of the measurement interval 705 closest to the second point in time T705. Note that in Fig. 7B the offset 706 has been exaggerated for illustration purposes. One way of implementing this modified measurement sequence is to shorten the interval between the last measurement period in a framing period and the first measurement interval in the next framing period by e.g. a quarter of a radio symbol. This would cause said offset 706 to be half a radio symbol. Note that the criteria described in connection with Fig. 4 is still fulfilled for the modified measurement interval sequence.

Another possible modification of the radio receiver 301 in Fig. 3 is to use the complex average A (see expression (3)) for the selected measurement interval in each framing period as the complex DC-offset estimate. This means that the DC-level estimator 605 of Fig. 6 could be eliminated and instead the selecor 604 could store this selected complex average directly in the storage 606. It is also of course possible to use more or fewer selected measurement intervals than four when calculating complex DC-offset estimates as running averages over several measurement intervals.

The radio receivers 301 and 801 both utilize a sequence of measurement intervals wherein the distance between each measurement interval corresponds to 32 radio symbols. This is more than twice the maximum timing advance value defined in

TIA/EIA IS-136 which implies that the previously stated criterion regarding the distance between measurement intervals is fulfilled for all radio communication systems complying with the TIA/EIA IS-136 specifications.

As previously discussed, when a radio receiver according to the present invention is used to receive transmissions of mobile stations operating in e.g. micro cells utilizing an effective maximum timing advance values which is less than the maximum timing advance value defined in TIA/EIA IS-136, it suffices that the distance between measurement intervals is greater than twice the effective maximum timing advance value used. The most extreme situation with regards to this aspect arises when the radio receiver is used in the context of small pico cells where no timing advance is used, i.e. the effective timing advance value is zero. In this extreme situation it suffices that the distance between each measurement interval is one sample period. Decreasing the distance between each measurement interval makes it possible to lengthen each measurement interval which enables the DC-offset estimate to be based on information from more radio symbols and thus provides for better DC-offset estimates. Both radio receiver 301 and radio receiver 801 could include configuring means enabling them to be configured by downloading parameters, either at installation or in operation, which controls the distance between each measurement period and the length of each measurement interval in accordance with the effective maximum timing advance value used in a certain context.

An analog front end of a radio receiver according to the invention need not generate two analog output signals from the analog front end. A radio receiver receiving e.g. 2ASK modulated radio signals, would generate a single analog output signal from an analog front end. A radio receiver for receiving quadrature modulated radio signals, e.g according to the TIA/EIA IS-136 specifications, may also generate a single analog output signal from an analog front end and instead derive a pair of digital

quadrature signals from the single analog output signal e.g. by using a hilbert transform.

Even though in the example scenarion of Fig. 1, the radio receiver 101 is used for the purpose of verifying that the second base station BS2 can receive the transmissions of the second mobile station MS2, the present invention is in no way limited to be used for such purpose. A radio receiver in the first base station BS1 which is used to receive transmissions from the mobile stations MS1-MS3 could also implement DC-offset estimation according to the present invention. Note however that in this situation, the time alignment procedure according to the TIA/EIA IS-136 specification ensures that the bursts transmitted by the different mobile stations MS1-MS3 are received without any overlap and hence the distance between each measurement interval could be made minimum, i.e. one sample period.

The invention is of course not restricted to be used only in TIA/EIA IS-136 compliant radio communication systems, but may also be used in connection with other TDMA-based air interface specifications such as those according to the Personal Digital Cellular (PDC) standard or the Global System for Mobile communications (GSM) standard and evolutions of said standards such as Enhanced Data rates for GSM (EDGE).

CLAIMS

1. A method for estimating a DC-offset (DC31, DC32) in at least one output signal (S32, S33) from an analog front end (302) of a radio receiver (301) in a TDMA-based radio communication system (PLMN1), wherein the radio receiver (301) is used to receive radio signals transmitted by mobile stations (MS1-MS3) on a radio carrier frequency (RCF2), the method comprising the steps of:

a) defining (501) a sequence (410) of measurement intervals such that for any first measurement interval (411) in the sequence (410) there is a subsequent second measurement interval (412) which together with the first measurement interval (411) fulfil two criteria with respect to a pattern of first regions (401) and second regions (402) wherein each first region (401) has a predetermined length (L1), the centres of two consecutive first regions (401) are separated by a distance equal to one time slot (D1) and each second region (402) extends between two consecutive first regions (401), the two criteria being that:

- the distance (D2) between the first measurement interval (411) and the second measurement interval (412) is greater than the length (L1) of one first region (401),

- the distance (D3) from the beginning of the first measurement interval (411) to the end of the second measurement interval (412) is less than the length (L2) of one second region (402);

b) generating the at least one analog output signal (S32, S33) by performing analog signal processing of received radio signals (S31) including the radio signals transmitted by the mobile stations (MS1-MS3) on the radio carrier frequency (RCF2) by the mobile stations (MS1-MS3);

c) deriving digital samples (S36, S37) from the at least one analog output signal (S32, S33);

d) estimating (504) a measure of received signal power in each measurement interval in a framing period (FP2) using the digital samples (S36, S37);

e) selecting (505) at least one of the measurement intervals in the framing period (FP2) in dependence of said estimated measures;

f) estimating (506) the DC-offset (DC31, DC32) using samples among said digital samples (S36, S37) which belong to said selected measurement interval;

2. A method according to claim 1 c h a r a c t e r i z e d by the first regions (401) being time intervals of a length (L1) corresponding to twice a maximum timing advance value in the communication system (PLMN1).

3. A method according to claim 1 c h a r a c t e r i z e d by the first regions (401) being time intervals of a length (L1) corresponding to twice an effective maximum timing advance value used when communicating on the radio carrier frequency (RCF2).

4. A method according to any one of claims 1-3 c h a r a c t er i z e d in defining the sequence (410) of measurement intervals such that, with respect to a first point in time (T701) coinciding with the beginning of a measurement interval (701), a second point in time (T702) one TDMA-frame period (703) after the first point in time (T701) also coincides with the beginning of a measurement interval (702).

5. A method according to any one of claims 1-3 c h a r a c t er i z e d in said sequence (410) of measurement intervals being defined such that, with respect to a first point in time (T704) coinciding with the beginning of a measurement interval (704), there is a small offset (706) in time between a second point in time (T705) one TDMA-frame period (703) after the first point in time (T704), and the beginning of the

measurement interval (705) closest to the second point in time (T705).

6. A method according to any one of claims 1-5 c h a r a c t e r i z e d in that the framing period is of length corresponding to one TDMA-frame.

7. A method according to any one of claims 1-5 c h a r a c t e r i z e d in that the framing period (FP2) is of length corresponding to a half TDMA-frame.

8. A method according to any one of claims 1-7 c h a r a c t e r i z e d by selecting in said step e) (505) the measurement interval with the weakest signal according to said estimated measures.

9. A method according to any one of claims 1-8 c h a r a c t e r i z e d by estimating in said step f) (506) the DC-offset (DC31, DC32) as an average of said samples belonging to the selected measurement interval.

10. A method according to any one of claims 1-8 c h a r a c t e r i z e d by estimating in said step f) (506) the DC-offset (DC31, DC32) as a running average of said samples belonging to the selected measurement interval in at least two consecutive framing periods (FP2).

11. A radio receiver (301) for receiving radio signals transmitted by mobile stations (MS1-MS3) on a radio carrier frequency (RCF2) in a TDMA-based radio communication system (PLMN1) comprising:

- an analog front end (302) generating at least one analog output signal (S32, S33) by performing analog signal processing of received radio signals (S31) including the radio signals transmitted on the radio carrier frequency (RCF2) by the mobile stations (MS1-MS3);

- deriving means (314, 315, 316, 318, 319, 320) connected to the analog front end (302) and deriving digital samples (S36, S37) from the at least one analog output signal (S32, S33);

- a DC-offset estimator (322) estimating a DC-offset (DC31, DC32) in the at least one analog output signal (S32, S33) from the analog front end (302);

c h a r a c t e r i z e d in the DC-offset estimator (322) comprising:

- sample arranging means (601) for grouping the digital samples (S36, S37) into sets of samples corresponding to measurement intervals (411, 412) in a sequence (410) of measurement intervals defined such that for any first measurement interval (411) in the sequence (410) there is a subsequent second measurement interval (412) which together with the first measurement interval (411) fulfill two criteria with respect to a pattern of first regions (401) and second regions (402) wherein each first region (401) have a predetermined length (L1), the centres of two consecutive first regions (401) are separated by a distance (D1) equal to one time slot and each second region (402) extends between two consecutive first regions (401),the two criteria being that:

the distance (D2) between the first measurement interval (411) and the second measurement (412) interval is greater than the length (L1) of one first region (401),

the distance (D3) from the beginning of the first measurement interval (411) to the end of the second measurement interval (412) is less than the length of one second region (402);

-power estimating means (602) estimating a measure of received signal power in each measurement interval in a framing period (FP2) using samples in the respective set of samples

corresponding to each measurement interval in the framing period (FP2);

-selecting means (604) for selecting at least one measurement interval in the framing period (FP2) in dependence of said estimated measures;

-level estimating means (605) estimating the DC-offset (DC31, DC32) using samples in the set of samples corresponding to said selected measurement interval.

12. A radio receiver (301) according to claim 11 c h a r a c t e r i z e d by the first regions (401) being time intervals of a length (L1) corresponding to twice a maximum timing advance value in the communication system (PLMN1).

13. A radio receiver (301) according to claim 11 c h a r a c t e r i z e d by the first regions (401) being time intervals of a length (L1) corresponding to twice an effective maximum timing advance value used when communicating on the radio carrier frequency (RCF2).

14. A radio receiver (301) according to any one of claims 11-13 c h a r a c t er i z e d in that the sequence of measurement intervals is defined such that, with respect to a first point in time (T701) coinciding with the beginning of a measurement interval (701), a second point in time (T702) one TDMA-frame period (703) after the first point in time (T701) also coincides with the beginning of a measurement interval (702).

15. A radio receiver according (301) to any one of claims 11-13 c h a r a c t er i z e d in that the sequence of measurement intervals is defined such that, with respect to a first point in time (T704) coinciding with the beginning of a measurement interval (704), there is a small offset (706) in time between a second point in time (T705) one TDMA-frame period (703) after the first point in time (T704), and the beginning of the

measurement interval (705) closest to the second point in time (T705).

16. A radio receiver according (301) to any one of claims 11-15 c h a r a c t e r i z e d by the framing period being of length corresponding to one TDMA-frame.

17. A radio receiver according (301) to any one of claims 11-15, c h a r a c t e r i z e d by the framing period (FP2) being of length corresponding to a half TDMA-frame.

18. A radio receiver according (301) to any one of claims 11-17 c h a r a c t e r i z e d in that the selecting means (604) is adapted to select the measurement interval with the weakest signal according to said estimated measures.

19. A radio receiver (301) according to any one of claims 11-18 c h a r a c t e r i z e d in that the level estimating means (605) is adapted to estimate the DC-offset (DC31, DC32) as an average of at least a subset of samples in the set of samples corresponding to the selected measurement interval.

20. A radio receiver according to any one of claims 11-18 c h a r a c t e r i z e d in that the level estimating means (605) is adapted to estimate the DC-offset (DC31, DC32) as a running average of at least a subset of samples in the set of samples corresponding to the selected measurement interval in at least two consecutive framing periods (FP2).

21. A radio receiver according to any one of claims 11-20 c h a r a c t e r i z e d in that the radio receiver comprises means (305-313) for deriving a pair of quadrature signals (S32-S33) from the received radio signals (S31).

AMENDED CLAIMS

[received by the International Bureau on 18 February 2000(18.02.2000); original claim 1 amended; remaining claims unchanged (1 page)]

1. A method for estimating a DC-offset (DC31, DC32) in at least one output signal (S32, S33) from an analog front end (302) of a radio receiver (301) in a TDMA-based radio communication system (PLMN1), wherein the radio receiver (301) is used to receive radio signals transmitted by mobile stations (MS1-MS3) on a radio carrier frequency (RCF2), the method comprising the steps of:

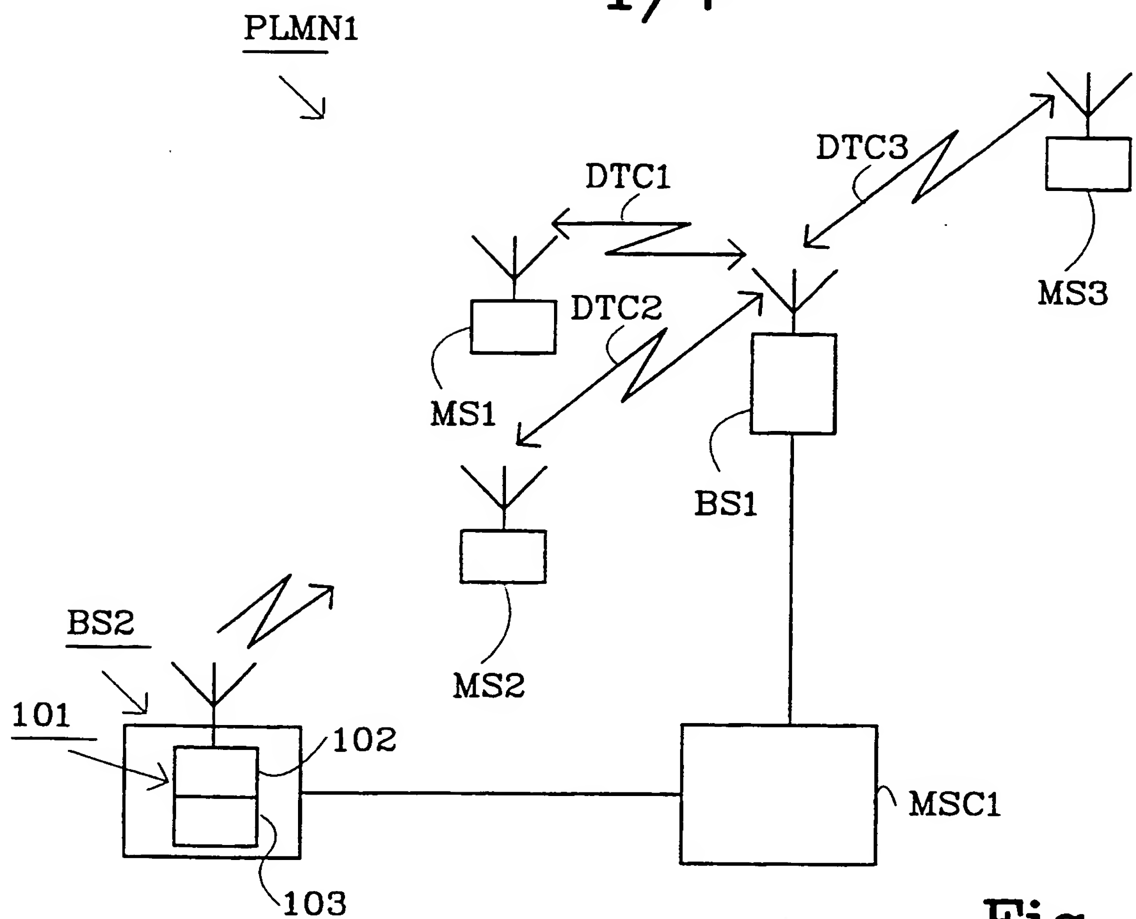
a) defining (501) a sequence (410) of measurement intervals such that for any first measurement interval (411) in the sequence (410) there is a subsequent second measurement interval (412) which together with the first measurement interval (411) fulfil two criteria with respect to a pattern of first regions (401) and second regions (402) wherein each first region (401) has a predetermined length (L1), the centres of two consecutive first regions (401) are separated by a distance equal to one time slot (D1) and each second region (402) extends between two consecutive first regions (401), the two criteria being that:

- the distance (D2) between the first measurement interval (411) and the second measurement interval (412) is greater than the length (L1) of one first region (401),
- the distance (D3) from the beginning of the first measurement interval (411) to the end of the second measurement interval (412) is less than the length (L2) of one second region (402);

b) generating the at least one analog output signal (S32, S33) by performing analog signal processing of received radio signals (S31) including the radio signals transmitted on the radio carrier frequency (RCF2) by the mobile stations (MS1-MS3);

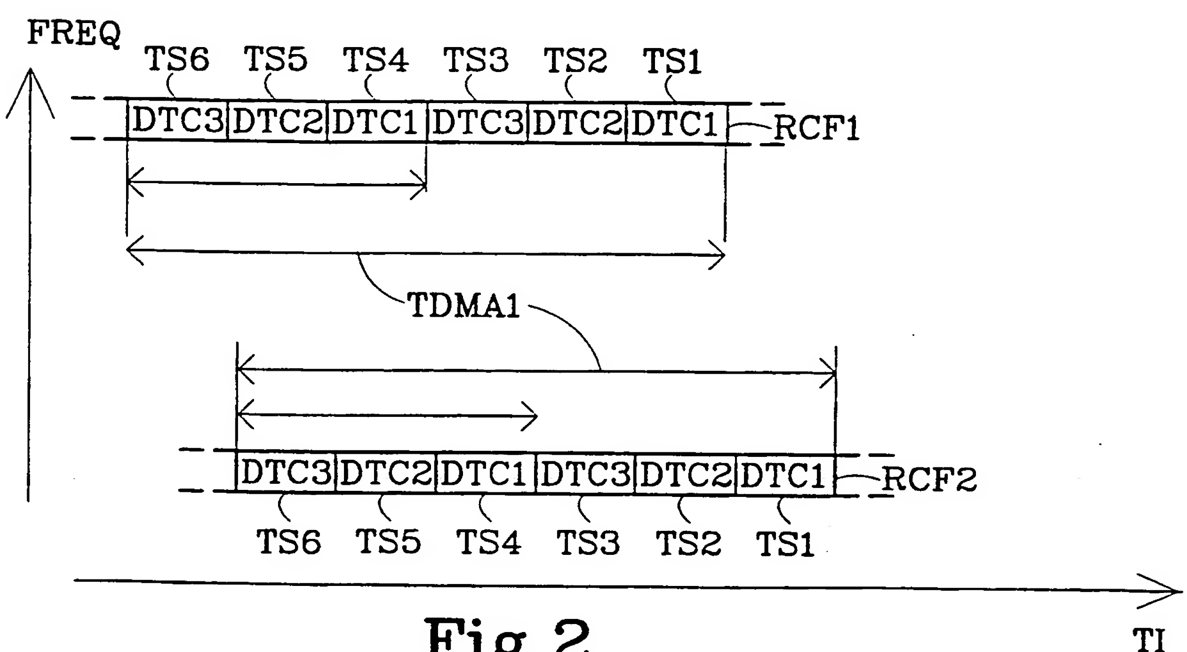
c) deriving digital samples (S36, S37) from the at least one analog output signal (S32, S33);

1/7



PLMN1
DTC1
DTC2
DTC3
MS1
MS2
MS3
BS1
BS2
101
102
103
MSC1

Fig. 1



FREQ
TS6 TS5 TS4 TS3 TS2 TS1
DTC3 DTC2 DTC1 DTC3 DTC2 DTC1
RCF1
TDMA1
DTC3 DTC2 DTC1 DTC3 DTC2 DTC1
RCF2
TS6 TS5 TS4 TS3 TS2 TS1
TI

Fig.2

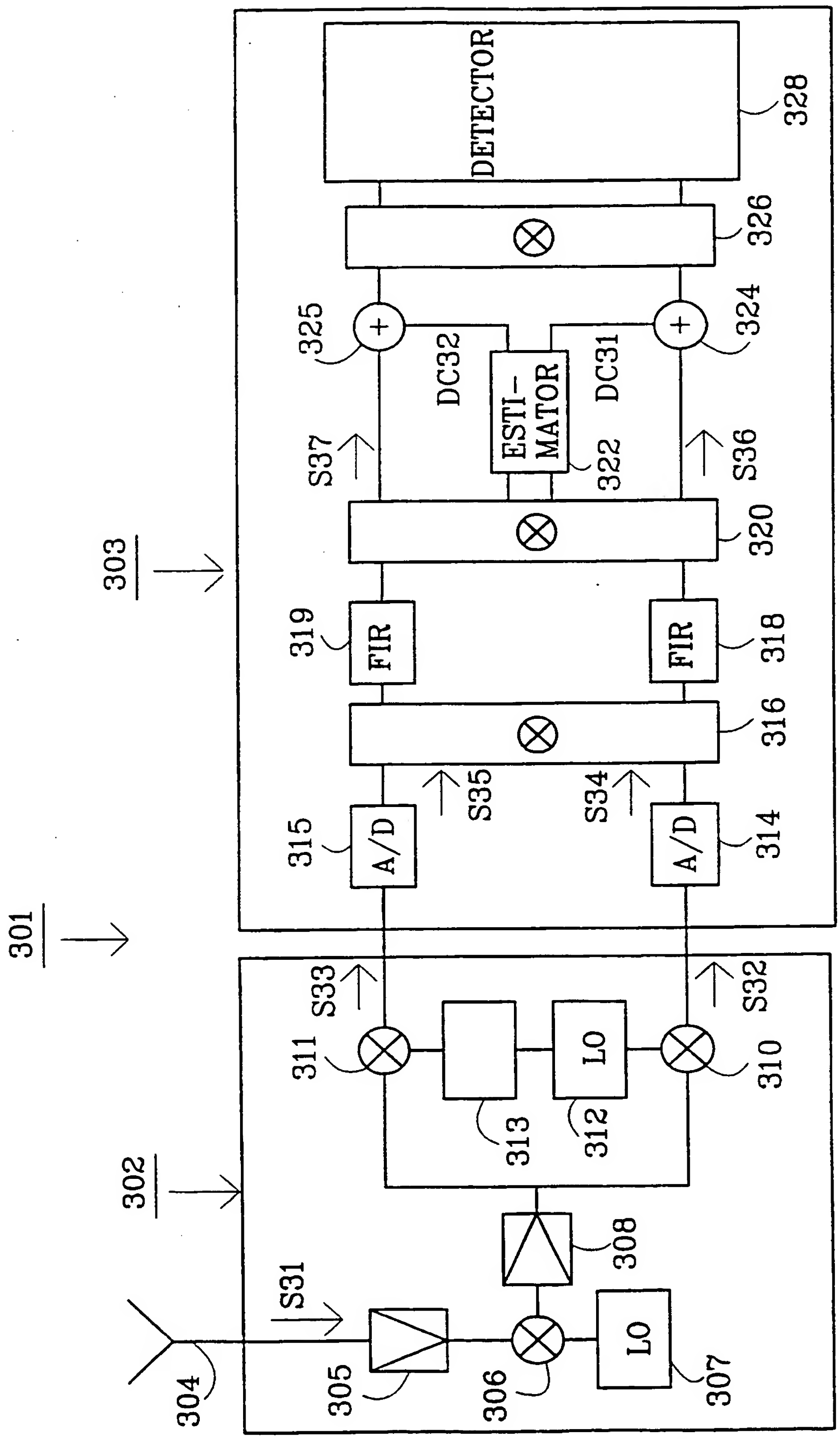

DETECTOR
328
326
325
324
DC32
ESTI-
MATOR
DC31
S37
322
S36
303
320
319
FIR
FIR
318
316
S35
S34
315
A/D
A/D
314
301
S33
S32
311
LO
310
313
312
302
308
S31
LO
304
305
306
307

Fig. 3

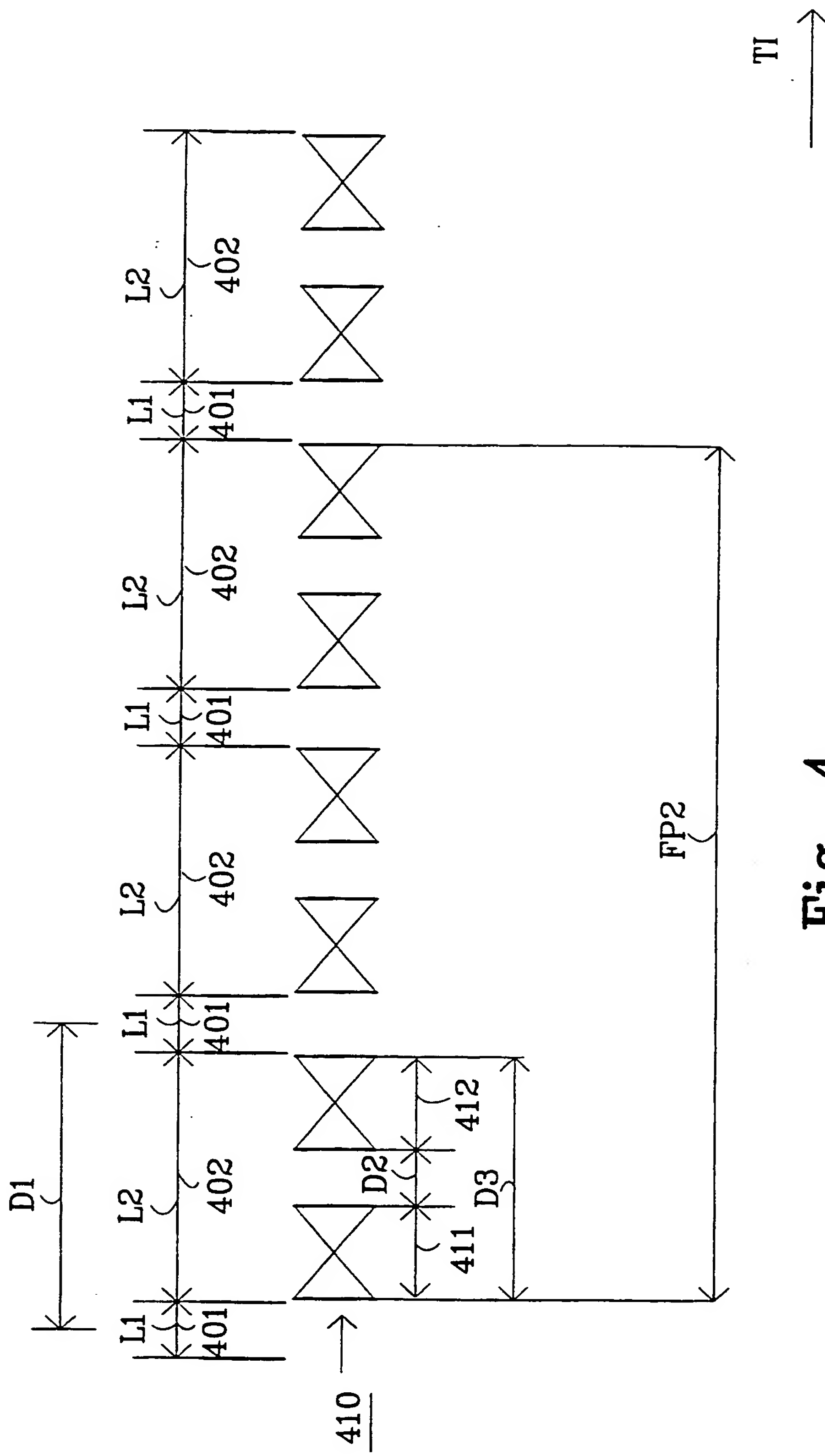

TI
L2
402
L1
401
L2
402
L1
401
L2
402
L1
401
D1
L2
402
L1
401
412
D2
D3
411
FP2
410

Fig. 4

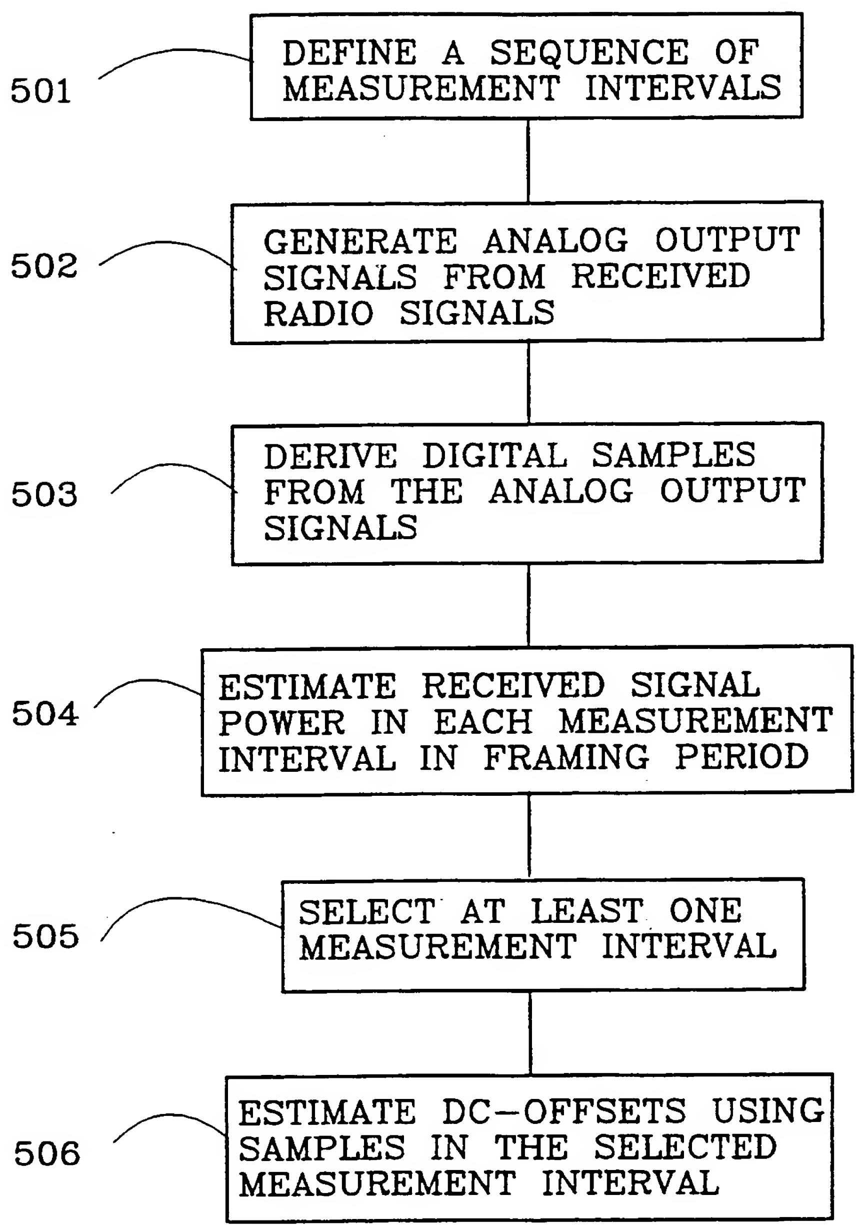
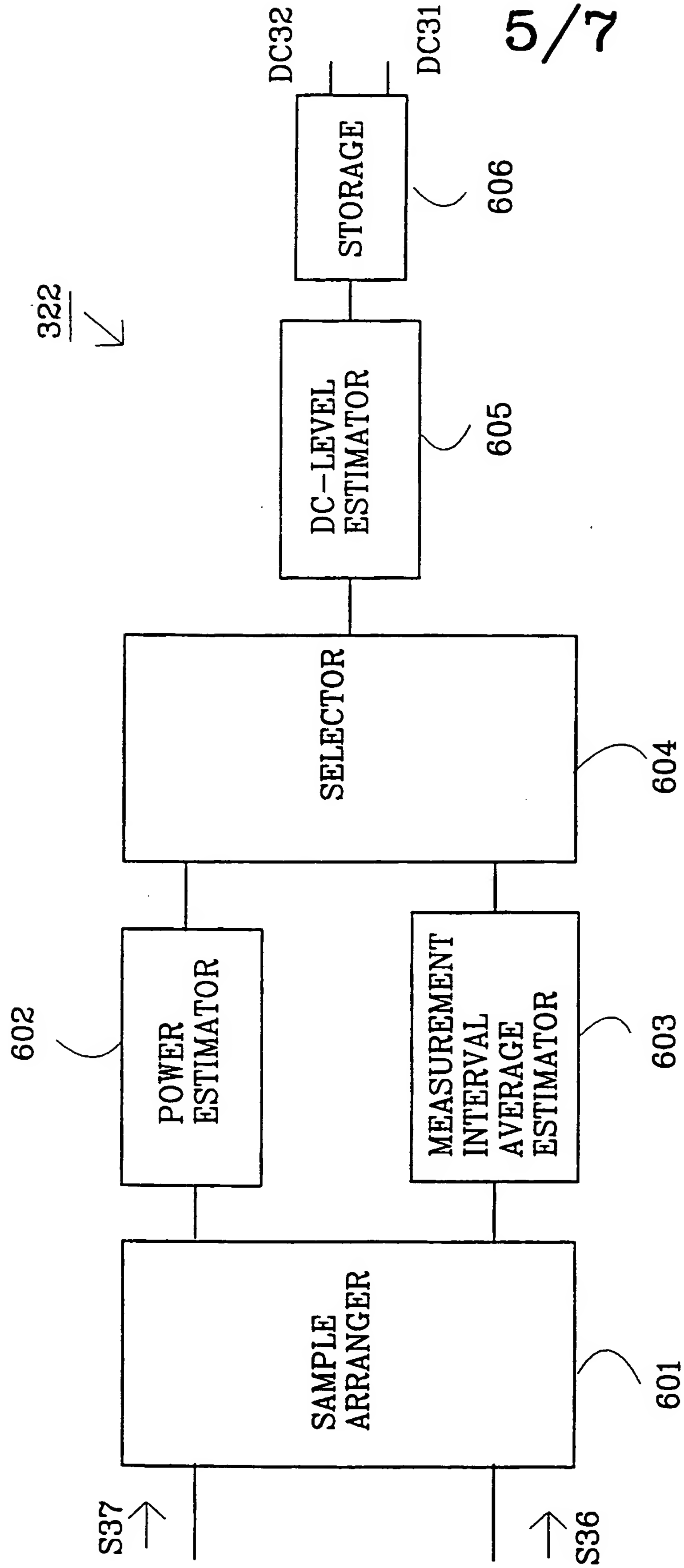

501
DEFINE A SEQUENCE OF MEASUREMENT INTERVALS
502
GENERATE ANALOG OUTPUT SIGNALS FROM RECEIVED RADIO SIGNALS
503
DERIVE DIGITAL SAMPLES FROM THE ANALOG OUTPUT SIGNALS
504
ESTIMATE RECEIVED SIGNAL POWER IN EACH MEASUREMENT INTERVAL IN FRAMING PERIOD
505
SELECT AT LEAST ONE MEASUREMENT INTERVAL
506
ESTIMATE DC-OFFSETS USING SAMPLES IN THE SELECTED MEASUREMENT INTERVAL

Fig. 5

5/7



DC32
DC31
STORAGE
606
322
DC-LEVEL ESTIMATOR
605
SELECTOR
604
POWER ESTIMATOR
602
MEASUREMENT INTERVAL AVERAGE ESTIMATOR
603
SAMPLE ARRANGER
601
S37
S36

Fig. 6

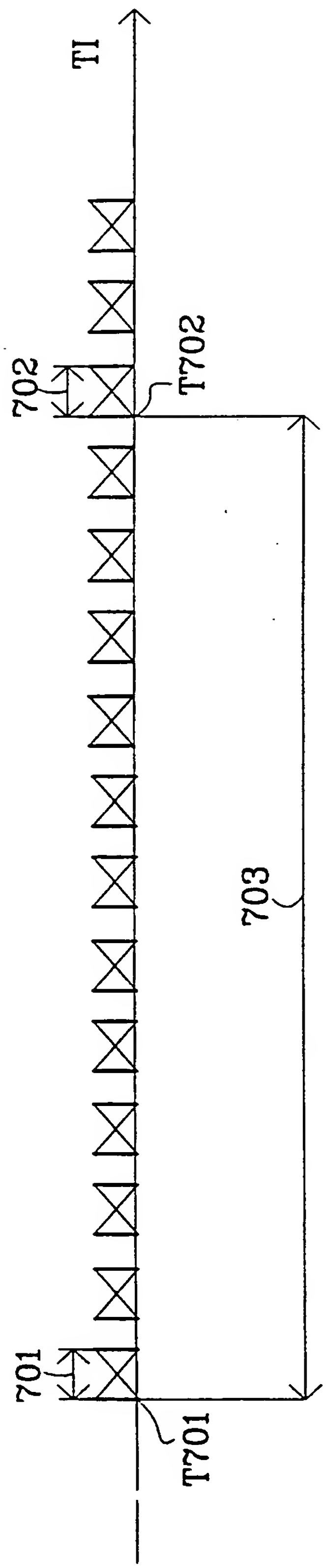


Fig. 7A

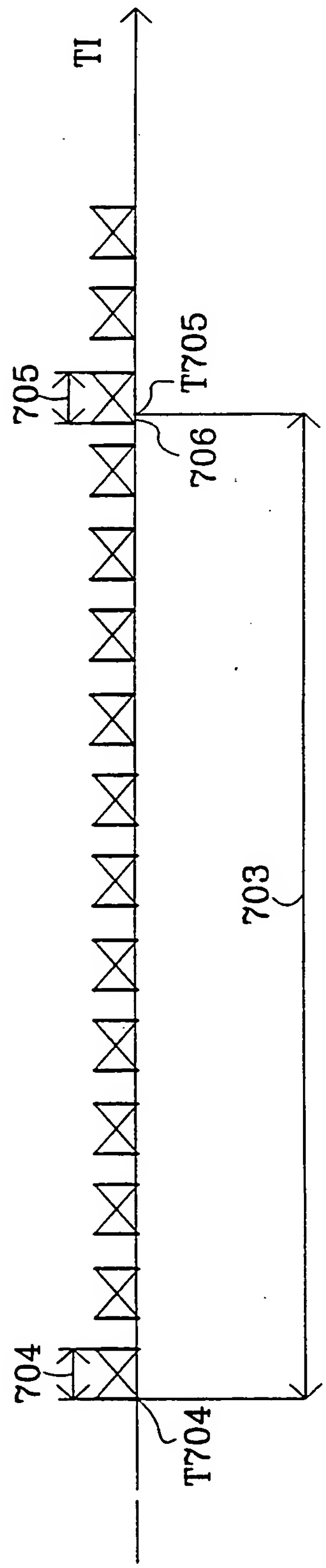


Fig. 7B

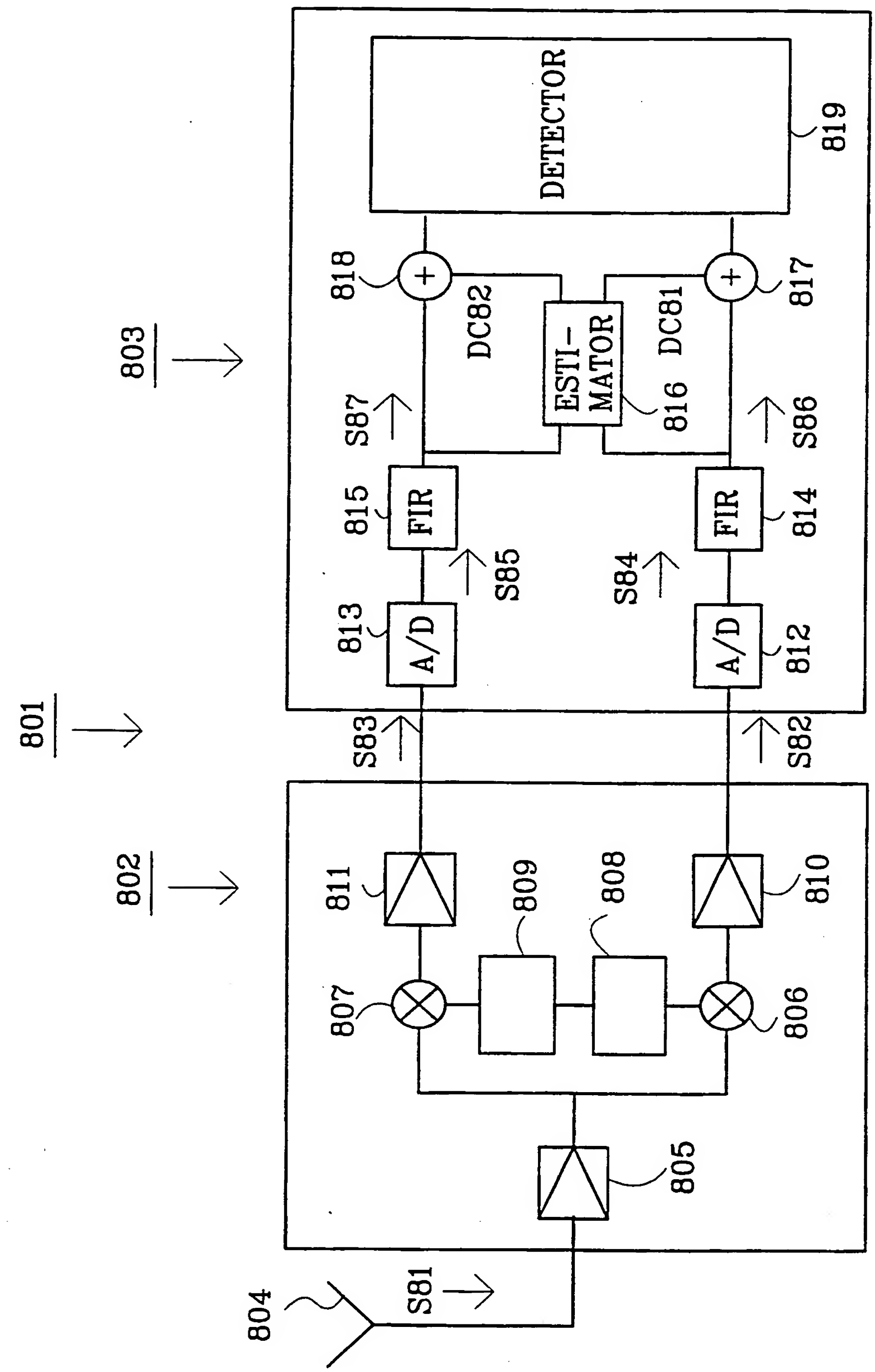

801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
DETECTOR
ESTI-
MATOR
DC81
DC82
FIR
FIR
A/D
A/D
S81
S82
S83
S84
S85
S86
S87

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01535

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 1/16, H04L 25/06, H04L 27/14, H04L 27/50
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9801981 A1 (TELEFONAKTIEBOLAGET LM ERICSSON), 15 January 1998 (15.01.98), abstract --	1-21
A	US 5422889 A (JOANNES M.J. SEVENHANS ET AL), 6 June 1995 (06.06.95), cited in the application --	1-21
A	US 5724653 A (THOMAS WESLEY BAKER ET AL), 3 March 1998 (03.03.98), abstract -- --------	1-21

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 February 2000	2000 -02- 16
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Fredrik Blomqvist/MN Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 99/01535

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9801981 A1	15/01/98	AU 3638597 A	02/02/98
		CA 2259608 A	15/01/98
		EP 0910913 A	28/04/99
		NO 990064 A	08/03/99
		US 5838735 A	17/11/98
US 5422889 A	06/06/95	DE 69228816 D,T	19/08/99
		EP 0594894 A,B	04/05/94
US 5724653 A	03/03/98	CA 2161167 A	21/06/96
		EP 0719013 A	26/06/96
		JP 8242262 A	17/09/96

REVISED VERSION*

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04B 1/16, H04L 25/06, 27/14	A1	(11) International Publication Number: WO 00/16490 (43) International Publication Date: 23 March 2000 (23.03.00)

(21) International Application Number: PCT/SE99/01535

(22) International Filing Date: 3 September 1999 (03.09.99)

(30) Priority Data:
9803133–9 15 September 1998 (15.09.98) SE

(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S–126 25 Stockholm (SE).

(72) Inventor: KORSFELDT, Dan; Älvdalsvägen 55, S–165 75 Hässelby (SE).

(74) Agent: ERICSSON RADIO SYSTEMS AB; Common Patent Dept., S–164 80 Stockholm (SE).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

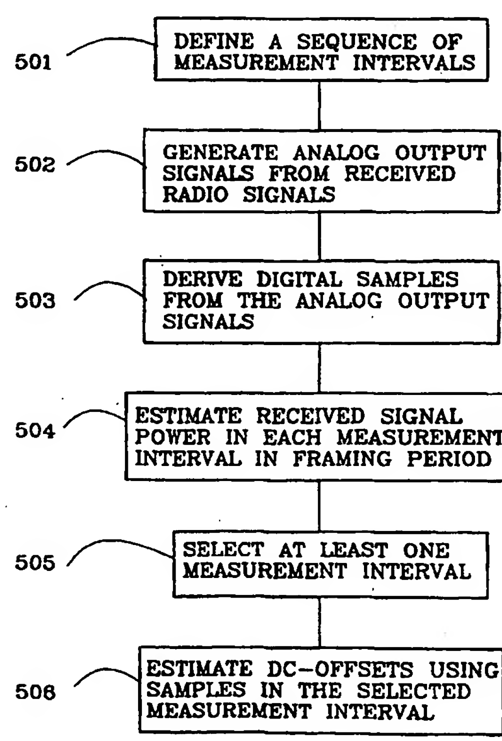
With a revised version of the international search report.
With amended claims.

(88) Date of publication of the revised version of the international search report: 11 May 2000 (11.05.00)

(54) Title: METHOD AND ARRANGEMENT IN A RADIO RECEIVER

(57) Abstract

The invention relates to a method and an arrangement for estimating a DC–offset in at least one analog output signal from an analog front end of a radio receiver in a TDMA–based radio communication system. A sequence of measurement intervals is defined (501) such that for each burst transmitted on a radio carrier frequency by mobile stations operating in a common cell, there is at least one measurement interval during which no overlap with a second burst occurs. The analog front end of the radio receiver generates (502) the analog output signal by performing analog signal processing of received radio signals. Digital samples are derived (503) from the analog output signal. A measure of received signal power in each measurement interval in a framing period is estimated (504). At least one measurement interval during the framing period is selected (505) in dependence of said measure. The DC–offset is estimated (506) using samples belonging to said selected measurement interval.



*(Referred to in PCT Gazette No. 19/2000, Section II)

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

REVISED VERSION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01535

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 1/16, H04L 25/06, H04L 27/14
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9801981 A1 (TELEFONAKTIEBOLAGET LM ERICSSON), 15 January 1998 (15.01.98), abstract --	1-21
A	US 5422889 A (JOANNES M.J. SEVENHANS ET AL), 6 June 1995 (06.06.95), cited in the application --	1-21
A	US 5724653 A (THOMAS WESLEY BAKER ET AL), 3 March 1998 (03.03.98), abstract -- --------	1-21

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 February 2000	08-03-2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Fredrik Blomqvist/MN Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

02/12/99

International application No.
PCT/SE 99/01535

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9801981 A1	15/01/98	AU 3638597 A	02/02/98
		CA 2259608 A	15/01/98
		EP 0910913 A	28/04/99
		NO 990064 A	08/03/99
		US 5838735 A	17/11/98
US 5422889 A	06/06/95	DE 69228816 D,T	19/08/99
		EP 0594894 A,B	04/05/94
US 5724653 A	03/03/98	CA 2161167 A	21/06/96
		EP 0719013 A	26/06/96
		JP 8242262 A	17/09/96